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THE

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GENERAL REVIEWS AND SUMMARIES

THE NEURONE

BY H. B. FERRIS

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The controversy as to the relationship of the endocellular network of Golgi (Binnennetz) and the trophospongium of Holmgren still continues. Ross (15) from his work on the nerve cells of the crayfish concludes that the trophospongium is a framework in the perikaryoplasm extending in from without and is non-nervous; and may contain nuclei and occasionally blood capillaries and serves both a nutritive and supporting function. Holmgren believed that Golgi's reticular apparatus and his trophospongium were identical and that the Saftkänalchen are developments by a dissolution process of the trophospongium. Ross thinks that the trophospongium is not only not identical with the reticular apparatus but entirely unrelated to it.

Cajal (1) studied the effect of experimental traumatism of the cerebrum on the reticular apparatus in the cortical cells. He found that an incision in the brain brings about complete destruction of the net only in those cells most severely injured. The net in cells near the incision while deformed in some instances showed no noteworthy abnormality. He thinks that this indicates that Golgi's net has considerable fixity of structure and firmness of texture since if it were of fluid consistence it would be found dispersed through the perikaryoplasm or massed together into larger droplets. Cajal also shows that the section of a peripheral axone has no effect on the structure of the Golgi apparatus. He believes that the Golgi net represents a canalicular system filled with a lipoid-containing substance reacting to silver impregnation and that these canals are for the most part fixed.

Pappenheimer (13) believes that the Golgi apparatus, Nissl bodies and mitochondria are different entities as they can be stained

in the same cell. As yet, however, no one has observed the net in the living cell. The Golgi net has been found in nearly all kinds of cells including those of the embryo and is described as breaking into fragments during mitosis and distributed evenly to the daughter cells. The net exhibits polarity, being found on the side of the nucleus toward the free surface and away from the blood supply. As fragmentation of the net occurs in ganglion cells after section of the axone, which however is denied by Cajal, and in lead and strychnine poisoning and traumatic injury, he believes that the net may be of solid form. Because of the capricious action of silver impregnations a new method of staining and more experimental work are needed to solve the morphology and genetic relationship of Golgi's reticular apparatus.

Little has been added recently to our knowledge of Nissl substance. There does not yet seem to be any absolute certainty as to whether this material exists in the form in which we find it in fixed and stained sections or whether it is simply a precipitation product. However, even if the latter supposition be true, it represents at least a chemical differentiation of the perikaryoplasm. Some observers claim that they can see Nissl bodies in the living cell, while others deny their existence there. Substances closely allied to these bodies have been found in many kinds of cells other than nerve cells and to such materials including Nissl bodies the general term chromidial substance is applied. Chemically Nissl bodies are generally believed to be a nucleo-protein containing iron which is elaborated by the nucleus.

Cowdry (3) has tried to solve the riddle of the "chromophile" cell at least as far as its finer morphology is concerned. He studied this condition in white mice and finds that chromophile cells vary in structure. Usually the cell as a whole and also the nucleus are shrunken. In some cells the mitochondria are increased either in number or sometimes as a diffuse material. As a rule no corresponding change in Nissl substance is noted, and Golgi's reticular apparatus seems to be unchanged.

Cowdry discovered some interesting facts relating to the distribution of the chromophile cells. They may exist singly or in groups of varying size in all stages of the chromophilic condition with unaltered cells scattered among them. He found chromophile cells more abundant in the cerebral and cerebellar cortex than anywhere else, rarely present in the olfactory bulb, corpora striata, thalami and cord, and infrequent in the medulla and the cranial

and spinal ganglia. He concludes that the chromophile condition is not an artefact but can be seen in the fresh cell where the material exists in the fluid state and can be stained vitally by methylene blue and that it is not associated with a pathological change in the animal. As chromophile cells are found in young mice as well as adults he considers that they are not an expression of senility.

The observations of Flesch (7) on chromophile cells do not wholly accord with those of Cowdry. Flesch finds more chromophile cells in all animals in the cells of the Gasserian ganglion than in the spinal ganglion and that chromophile cells are larger than the normal cell. Also he finds chromophile cells are less in number in young animals than old. As the nerve cells of the embryo are exclusively mesochrome he believes that both chromophobe and chromophile forms are derived from the mesochrome.

During the last three years there has been an intensive study of the mitochondria by various observers. Duesberg has suggested in order to clarify the nomenclature that the term chondriosomes be adopted as the general term instead of mitochondria, which is reserved for the granular form while the filamentous form he calls chondriocontes. In studying the nerve cells of fish embryos he finds chondriosomes in the form of granules already uniting to form filaments parallel to the long axis of the cell as early as three days after fertilization. Meves and Duesberg believe that in cell division there is an equal partition of chondriosomes between the two daughter cells.

The Lewises (11) have given a very interesting account of the mitochondria observed in the living cells of the chick in cultures. They find that the mitochondria may be evenly scattered through the perikaryoplasm or radiating around the central body or at one side of the nucleus. They change shape, size and number, even branching and forming a network, and move about passing from one cell to another through anastomosing processes and migrate from nucleus to periphery and return. An increase in size and number occurs during the growth period and just before mitosis. They are of the opinion that the mitochondria have a somewhat characteristic appearance in the different kinds of cells and in the nerve cell are more likely to be small granules and short rods. CO_2 and acids cause them to degenerate, heat causes them to change shape and decrease in number, alkalies and hypotonic solutions cause them to swell, hypertonic solutions shrink them and chloroform and ether dissolve them. They found no evidence that either glycogen granules

or fat droplets are formed from them or that they divide during mitosis or are evenly distributed to the daughter cells as some observers describe. There is some evidence that mitochondria decrease as nerve cells become senile and as the result of fatigue.

Nicholson (12) thinks that there are differences in quality and form in the mitochondria in different cells of the central nervous system of white mice. In the cerebral and ventral horn cells they are filamentous, while rod-like and granular forms are characteristic of the cells in the mesencephalic nucleus of the 5th nerve and the Gasserian ganglion. Also in the same cell they are more likely to be granular near the nucleus and always elongated in the processes. They may lie between the Nissl bodies or be buried in them. Also there are microchemical differences as some are more readily soluble in acetic acid than others. In view of the work of the Lewises, who have shown that mitochondria are constantly changing in shape, one is sceptical of the significance of these differences described.

Thurlow (17) studied mitochondria in motor and sensory cells but found no characteristic differences. Some sensory cells contained more mitochondria than motor cells and others less. The number of mitochondria however in the cells of the same group were about the same and he believes that there is a definite mitochondrial cytoplasmic ratio.

Little is known of the relation of mitochondria to diseased conditions. They may have some relation to fatty degeneration as they have been shown to have some connection with the formation of fat droplets in phosphorous poisoning. As cholin is found in the cerebro-spinal fluid in organic in contradistinction to functional disease of the nervous system there is some evidence that the mitochondria are connected with its formation, Cowdry (4) suggests that a study of the mitochondrial content of nerve cells in disease of the nervous system may yield valuable information.

The evidence from various sources seems to show that mitochondria are definite, discrete, formed elements found in all kinds of cells and at all ages and chemically are a lipoid albumen. They are not related genetically to the neurofibrils, Nissl bodies nor the Golgi net. Functionally they are connected with the fundamental metabolic processes such as occur in all cells, possibly of a respiratory nature. They are therefore less specific substances than Nissl bodies or the neurofibrils.

Turning to more general facts about the neurone Carpenter and Conel find in sympathetic ganglia not only Dogiel's motor type of

cell with thick dendrites but also his sensory type with slender dendrites. As they also find the intermediate type, they conclude that Dogiel's types are only the extremes of the variations occurring in multipolar sympathetic cells.

Greenman (8) finds that the number of fibers in the peroneal nerve of the albino rat increases with age until 250 days is reached and the number begins to decrease after 335 days of age. Also the sectional area of the fibers decrease with advancing age. Electrical stimulation has no effect on the sectional area of the nerve fibers.

Ransom (14) has shown that in spinal ganglia there are all sorts of variations from the fundamental type of cell with T-shaped axones and that simple unipolar cells may be transformed under experimental conditions into complex multipolar cells and such cells may return to their original simple form. This brings up the question of the possibility of the individual neurone in situ changing its form.

There has been a renewal of the attempt begun a number of years ago by Hodge to try to correlate the various structures in the nerve cell with their function. Smallwood and Phillips studied the size of the nucleus in the nerve cells of the antennal lobes of the bee and found that the nuclei vary greatly during all the stages of the bee and therefore question the validity of Crile's conclusion that the nuclei of nerve cells are smaller in shock and Hodge's conclusion that they are smaller in fatigue.

Dolley (5) and his pupils in various papers have tried to show a correlation between structure and function in the Purkinje cell of the cerebellum. Dolley holds that there is a constant relation of the volume of the nucleus to the volume of cytoplasm in the resting cell. The relation he calls the nuclear-plasma coefficient $\frac{\text{volume of cytoplasm}}{\text{volume of nucleus}}$. He contends that the resting cell of Purkinje has no basichromatin except in the karyosome, that the plasma shows no edema nor vacuolation and also that there is a certain mass relation of nucleus to cytoplasm. During activity the cell and nucleus shrink, the chromatin decreases and there is an "upset" of the nucleus-plasma relation in favor of the nucleus, *i. e.*, nucleus is relatively large, and a dissolution of Nissl bodies occur. The coefficient continues to decrease as activity proceeds.

Kocher (10) studied the effects of activity on the cells of the motor cortex, in the spinal cord and cerebellum in dogs and cats in carefully controlled experiments. He was unable to find any of the various changes described by Dolley as resulting from fatigue, such

as changes in Nissl bodies, changes in actual size or relative size of nucleus or in any of the other constituents of the nerve cell. The impartial observer apparently must reserve for the present his judgment in the matter.

Kappers (9) in a long article defends his theory of neurobiotaxis. This theory assumes that the chief dendrite grows out toward, and its cell body shifts toward, the direction from which the stimulus proceeds, provided that the stimulation is of a nature that these cells respond to, *i. e.*, a correlation exists. He considers this growth of dendrites toward the source of stimulus (stimulo-petal tropism) similar to a kathodic tropism and the growth of the axones away from the stimulus (stimulo-fugal tropism) similar to an anodic tropism.

This theory is an attempt to explain the growth of the dendrites in one direction and the axone in the opposite and the shifting of groups of cells which occur during development. He concluded that correlated function is the fundamental factor in the arrangement of the cells and axones in the nervous system. The theory of neurobiotaxis seems more like a statement of an observed phenomenon than a satisfactory explanation of it. The anatomist has now brought our knowledge of the internal morphology of the neurone to the point where the assistance of the biological chemist and the pathologist is needed to increase our knowledge of the relation of structure to function.

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REFLEX MECHANISMS AND THE PHYSIOLOGY OF NERVE AND MUSCLE

BY EDWIN B. HOLT

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The posthumous book of Keith Lucas (13), in Starling's Monograph series, has been arranged for the press by E. D. Adrian from manuscript left by the author. It sums up in very clear form the recent work on the conduction of the nervous impulse and gives what is virtually a digest of the brilliant investigations of Lucas and Adrian themselves. Their chief experimental device for measuring the intensity of a nervous impulse has been to "set it to face a tract of nerve in which it will undergo a decrement, and determine how far it is able to travel before it is extinguished." Such a region of decrement can be produced by narcotics and by other means. This method seems to have yielded a final demonstration of the all-or-none law for normal nerve fibres, and the authors conclude that, "when a motor nerve is artificially excited with stimuli of varying strengths, the graded contraction of the muscle results solely from variation in the number of fibres brought into action." The separate contraction of isolated muscle fibres has now been

directly observed by Pratt (16) and Eisenberger (3). Under three circumstances, however, the nervous impulse is susceptible of quantitative variation: first, in a region of decrement, where as it travels it is gradually reduced in intensity and may be extinguished; second, if it comes so immediately after a preceding impulse as to be travelling always in tissue which has been left in the "relative refractory" state by the preceding impulse. Here, "the impairment in conduction is of a different kind from that brought about by a narcotic. The nerve does not conduct with a decrement, but it will not conduct impulses of the normal intensity." The third case is that in which a (slightly later) second impulse is traveling in tissue which a preceding impulse has left in the "phase of supernormal conduction." For the process of recovery in nerve after the passage of an impulse presents three stages—the absolute refractory, the relative refractory, and the supernormal.

The authors favor the "hypothesis" that summation in nerve depends on this phase of supernormal conduction. A second, supernormal impulse will be able to travel through a region of decrement in which the preceding impulse (of merely normal, "all-or-none" intensity) was extinguished. And Lucas regards the myo-neural junction as a region of decrement, for "the supposition of a decrement in conduction is the only hypothesis yet put forward which gives an account of all the known phenomena of conduction in the junctional tissue between nerve and skeletal muscle." Inhibition is explained by means of the reduction that an impulse suffers when it is timed to fall in the relative refractory phase left by a preceding impulse. "The second stimulus falls at such a time that its impulse passes down the nerve in this reduced condition. On reaching the junctional tissue it cannot pass through, probably because that tissue conducts with a decrement. The reduced impulse has, however, passed along the nerve and left there a new state of impaired conduction; consequently the third impulse, if suitably timed, will also be propagated in a reduced condition and fail to pass the decrement. This state of things can be continued as long as the stimuli fall on the nerve with the appropriate frequency." But the author does not present this as "a satisfactory explanation of all forms of central inhibition."

The last chapter, on Central Inhibition, is mainly by Adrian and includes an interesting though somewhat hypothetical diagram of the mechanism of reciprocal innervation (Sherrington's "motor half-centers"). The central nervous system is pictured "as a net-

work of conductors having different refractory periods, communicating through regions of decrement, easily fatigued and capable of setting up a train of impulses in answer to a single stimulus." Throughout the volume prominence is given to the all-or-none law. Lucas believes "that nerve uses oxygen and gives off carbon-dioxide when it is conducting nervous impulses," and "that by its very nature the nervous impulse is dependent for its intensity only on the conditions which it encounters during conduction and not on the intensity with which it is initiated."

Another paper by Lucas (**14**) deals with summation in the claw mechanism of Astacus. In the adductor claw (nerve-muscle preparation) there is a local summation phenomenon which is due to the summation of two incomplete local excitatory processes, as is shown by the fact that this summation is not found when the two stimuli fall on separate parts of the nerve tissue. There is also a second type, the "summation of propagated disturbances," which takes place in a region of decrement and appears to be of the kind mentioned in the second preceding paragraph above. This summation probably takes place at the myo-neural junction, but Lucas makes the reservation that "it is not clear whether the arrival of the second impulse in the supernormal phase of the nerve would be a legitimate reason for its better conduction in the junctional tissue, since the course of recovery in the latter might be either quicker or slower than it is in the nerve." This statement puts the matter rather more tentatively than does the presentation in Lucas's book (**13**).

That the all-or-none law holds for normal muscle as well as for nerve seems now to have been definitely proved, by means of the ingenious "capillary electrode" invented by Pratt (**15**). One end of a glass tube is closed by fusing, and the fused end is allowed to elongate slightly under the influence of gravity. When cool it is very carefully ground away until the lumen of the tube just begins to appear on the ground surface of the end. Such a tube now makes an excellent liquid electrode in which the electrically active surface may be as small as 4μ in diameter, or even less. Since the single fibers of vertebrate muscle are considerably larger than this (20 to 50μ in the sartorius of frog), "it seems certain that a delicate adjustment of current will in the majority of instances cause an excitation of but one fiber, provided its surface be sufficiently near the pore."

Using this capillary electrode, both Pratt (**15**, **16**) and Eisen-

berger (3) have been able to observe directly the isolated contraction of single muscle fibers. Eisenberger gives excellent photographs. Both authors show that the minimal contraction of a single muscle fiber follows the all-or-none law. If the fiber is fatigued by repeated stimulation at constant (minimal) intensity, the contraction does not gradually diminish. It remains at constant height, until (with sufficient fatigue) the series of contractions is suddenly broken off. And in general, "a continuous gradient of stimulation induces a discontinuous gradient of contraction in skeletal muscle."

Pratt (16) uses the term "*quantal* to express both substantively and adjectively the conception of structural carriers [the muscle fiber] of such integers of energy in effects discontinuously graded. . . . A quantal, therefore, may be any all-or-none or, as Verworn has aptly termed it, *isobolic* system. A series of responsive values would be quantal when composed of discontinuous steps depending upon the additive discharge of successive quantals." The units in a muscle obey the all-or-none law, and the muscle as a whole obeys a quantal principle, although as a whole it notoriously appears to violate the all-or-none law. "Gradation of quick response is fibral; not fibrillar or sarcomeric. That is, the fiber as a whole forms the unit employed in effects of multiple constitution. It is to be assumed that in the response of a fiber all of the sarcostyles take part to the full dynamic capacity of each and every segment."

Another contribution of fundamental importance is a study by Forbes and Rappleye (5) of "the action currents of human muscles in voluntary contraction under as widely varying temperatures as possible and with as little variation as possible in the temperature of the central nervous system.' . . . 'The records showed with perfect uniformity a decrease in frequency together with an increase in amplitude of the excursions whenever the arm was chilled, and in most cases a somewhat less pronounced increase in frequency with a decrease in amplitude when the arm was heated.' . . . 'It seems to us to follow from the above results that the rhythm of action currents appearing in the electromyogram of human voluntary contraction is no direct index of the rhythm of central innervation involved in the act. The change of rhythm attending change of temperature would be inexplicable on any such basis. For why should a change in the temperature of the muscle cause a change in the frequency of discharge of impulses from the ganglion cells whose temperature remains constant? This might conceivably be

if afferent impulses coming from the chilled muscle so modified the nerve center as to alter its frequency of discharge; but this assumption is far-fetched and involves nervous influences to which we know of no analogy. . . . We agree, then, with Buchanan that the rhythm in the muscle does not follow the rhythm of motor nerve impulses, but depends rather on the condition of the muscle itself." Now Piper and Beritoff have shown that a frog's muscle can follow with separate action currents the rhythm of nerve impulses excited by induction shocks even up to the frequency of 250 or 300 per second: and in man the possible frequency of the muscle is probably higher. "We have here an apparent paradox; the muscle can respond separately to more than 300 nerve impulses per second, but when played on by the stream of impulses coming from the ganglion cells it responds with frequencies which may be evenly graded from 30 to 50 or more per second according to its own temparature." And the authors believe that the impulses coming from the ganglion cells have a frequency that is not less than 300 to 400, and may conceivably have an extreme frequency of 5,000 per second.

Now "it is not permissible to assume that any tissue has one 'specific rhythm' peculiar to itself. The rhythm or response obtainable from a tissue is a resultant of the curve of recovering excitability and the strength of stimuli employed. In the case of muscle excited through its nerve we have two refractory periods to consider, that of the muscle itself and that of the nerve, and also the lowered stimulating value of the impulse traversing the nerve during its relative refractory period. . . . Lucas has shown that in a fatigued nerve-muscle preparation the resistance to the passage of a propagated disturbance increases at the neuromuscular junction. The result of this in the case of voluntary contraction, maintained, as we contend, by subnormal nerve impulses of high frequency, would be to cut down still further the stimulating value of the impulses at the point where they act on the muscle fibers, and consequently to delay until nearer the end of their [the muscle fibers'] relative refractory period the time at which they would respond." In other words, after each stimulation of the muscle some of the next succeeding nerve impulses would reach the muscle during its more or less refractory period, and would so be lost: while a just later impulse would again stimulate the muscle. "Thus, without change in the nerve impulse frequency, the mere raising of resistance in the neuromuscular junction [as by cooling] would slow down the rhythm of muscular response." The discussion cannot be adequately

summarized here, and is well worth reading in the original. In agreement with Lucas, Pratt, and Eisenberger, the authors find themselves "forced to the view that in voluntary contraction gradation must be conditioned by gradation in the number of muscle fibers in action at a given moment, the doctrine of fractional activity, as Stiles has termed it."

An experiment of Gruber (6) on vasomotor changes in cats narcotized with urethane, seems to bear somewhat on the paper just reported. Electrical stimuli were given to the central end of cut saphenous, peroneal, ulnar, radial, median, and popliteal nerves, successively, and the vasomotor changes were observed on the carotid and on the femoral, artery. "With the same strength of stimulus pressor [vasoconstrictor] and depressor [vasodilator] results are obtained by varying the rate of stimulation from 1 to 20 stimuli per second." The more rapid rates of stimulation usually bring about vasoconstriction. While it may be that "summation" occurs with the more rapid stimulation, "it does not seem probable in this case where the strength is more than 400 times threshold that the phenomenon of summation can explain the different effects obtained with these rates of 1 per second and 20 per second interruptions."

Sherrington showed in 1892 that, in vertebrates, strychnine (which undoubtedly lowers the myo-neural resistance) abolishes the reciprocal inhibition of antagonistic muscles by converting inhibitions into excitations. Knowlton and Moore (8) now report a similar phenomenon in the earthworm. Normally a single excitation elicits "a shortening of the worm anterior to the point of stimulation and a lengthening posterior to that point." This "involves reciprocal innervation since a contraction of the circular muscles is associated with relaxation of the longitudinal ones." When treated with strychnine, the earthworm shows a shortening instead of lengthening of the portion posterior to the point stimulated. The posterior (as well as the anterior) muscles, both circular and longitudinal, now contract and "since the longitudinal muscles are the more powerful the net result is a shortening of the worm in a rigid condition."

Fletcher and Hopkins (4), in the Croonian Lecture of 1915, discuss the respiratory process in muscle. They contend that the muscle is a chemical, rather than a heat, engine. "The special proccesses which, when they occur within a muscle fiber, culminate in a contraction, make no call upon an oxygen supply; they proceed

anaërobically. The oxidations which are always associated with muscular activity are separated in time from that moment in which mechanical energy is liberated. They occur immediately afterwards, and are concerned not with the induction of the mechanical act, but with a restoration of the *status quo ante*." . . . "The work actually done, will bear variable and quite accidental relations to the heat production." The main reservoir of energy in a muscle is to be sought in its carbohydrate stores. "Placed in the right locality within the muscle, sugar, by a non-oxidative yield of acid at the right moment, and by a subsequent oxidation of this at another right moment, can yield its total energy in a manner exactly suited to serve the peculiar machinery in which, so to speak, it finds itself." Langley (**11**) has studied in the muscle of living animals the processes of loss of weight through atrophy, of fibrillation, and of regeneration and the recovery of muscular function after nerve suture, nerve section, and nerve insertion. Langley and Itagaki (**9**) have made determinations on the oxygen use of denervated muscles on one side of the body compared with that of undenervated muscles on the opposite side of the same animal (cat). "In all cases a much greater oxygen use per gram per minute was found to be present in the denervated muscles. We conclude from this that the atrophy of denervated muscle is not solely due to a decreased power of repair, the breakdown remaining constant, but that it must be due chiefly to an increase in the rate of breakdown of the muscle substance." This latter may be connected with the fibrillation of the muscle which begins soon after denervation.

Gruber (**7**) observes "that adrenalin does not lower the threshold of a normal, unfatigued muscle. . . . In the fatigued unaltered nerve muscle adrenalin may increase the height of muscular contraction by a twofold action, by improvement of the blood supply (vasodilation) and by its chemical action upon some substances in the muscle." Rogers, Coombs and Rahe (**17**) describe a special mode of preparing an extract, which they call a "residue," from endocrine glands. They find that "residues" from fresh thyroid, parathyroid, and adrenal (and from no other endocrine) glands are effective in reënertizing fatigued voluntary muscle (cat). The extracts were given by intravenous injection, and their point of action appears to be in or near the muscle fiber itself: the effects seem not to come *via* the nervous apparatus.

Adrian (**1**) has given a simple account, for clinicians, of Lapicque's two terms "rheobase" and "chronaxie." "If we take a

simple excitable structure, such as an isolated nerve-fiber or striated muscle fiber, and use as stimulus the simplest and most easily adjusted form of current, namely a galvanic current of known strength and known duration, we find that there are two limiting factors which determine the success or failure of the stimulus. These are (1) a certain minimal strength, and (2) a certain minimal duration. However strong it may be the current will not excite if its duration is shorter than a certain time, and its strength cannot be reduced below a certain level, however the duration may be prolonged. Within these limits the necessary strength and duration are related in the following way. For all durations which are long compared with the minimal duration the strength of current required to excite remains constant at its minimal value. As the minimal duration is approached the strength must be increased, and the increase becomes more and more rapid as the duration is reduced." For practical purposes the function "may be defined by two factors which Lapicque has called the rheobase and the chronaxie. The rheobase is equal to the strength of current required to excite when the duration is infinite, and we may consider it as depending on the absolute excitability of the tissue in question. The chronaxie depends on the rapidity of the excitation process, and it is equal to the duration at which the current must be increased to twice its minimal strength," *i. e.*, to twice the rheobase. "The rheobase is of little practical importance as an index of the condition of the tissue, for it is impossible to compare it in different cases with any profit unless the conditions of stimulation are very accurately controlled as to resistance, current flow per unit area, etc. On the other hand the chronaxie can be measured without any of these precautions, since we need only determine the duration at which the current strength must be twice the threshold value, and the disposition of electrodes, resistances, etc., does not matter. It is found to be remarkably constant for similar tissues examined under similar conditions of temperature, perfusing fluid, etc. Further, it shows very great variations in different types of tissue. . . . In the chronaxie we have a constant which is definitely related to the state of the excitatory mechanism of the tissue."

In a study of cutaneous sensation after nerve-division Boring (2) includes a valuable discussion of Head's attempted division of cutaneous sensibility into "protopathic" and "epicritic" systems. For reasons which seem to the reviewer good, Boring does not accept Head's hypothesis.

Lashley (12) has studied the accuracy of voluntary movement in a young man who, "as a result of gun-shot injury to the spinal cord," has a partial anæsthesia of both legs with motor paralysis of the muscles below the knees. It was not possible to learn "the exact extent of the lesion, . . . but the clinical picture indicates an extensive destruction of the dorsal bundles in the second or third lumbar segment of the cord with invasion of the dorsal horns or injury to the afferent roots in the sacral region sufficient to abolish the tendon reflexes." The degree of anæsthesia of the patient was determined from his introspective judgments when his leg was placed in various positions or moved through various angles by the experimenter. When seated, the patient could not voluntarily maintain any other position than that of hyperextension of the knee, and this for but a short time. "There was momentary maintenance of position, relaxation without recognition of the movement, and later an illusion of relaxation." The patient would often not know (in passive movements) in which direction, to say nothing of the distance, his lower leg was moved. The author believes that the anæsthesia of the leg was "sufficiently extensive to exclude any reflex control of the accuracy of movement based upon cortical excitations arising from the moving limb." Nevertheless the patient could move his lower leg in either direction as designated, and could so far control the (verbally designated) distance of his movement as at least to move farther when the distance suggested was longer, and *vice versa*. He generally moved too far. And he could reproduce a voluntary movement of his own with an accuracy that compares very fairly with that of a normal subject. The author believes that the extent of movement was not determined merely "by the control of the duration of the excitation of motor pathways."

Langley and Hashimoto (10) have an interesting paper on the course of nerve bundles in the nerve trunk. It appears that nerve plexuses are frequent between the elements combined in a nerve trunk—plexuses of fibers in small nerves, of bundles in larger nerves. Such plexuses are found especially in the vicinity of the points where nerve branchings are given off. "The complexity of the lower plexuses in the sciatic of the larger mammals makes it, we think, certain that, so far as dissection goes, no bundle above the plexus can be said to correspond even approximately with any bundle below it." The time taken for recovery of function after nerve-division is not altogether the time taken by the regeneration of the

nerve-fibers: there is a further time required for the reëducation of nerve connections, especially central ones.

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TROPISMS AND INSTINCTIVE ACTIVITIES

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Chemotropism and Feeding Reactions.—Kepner and Edwards (13) find that the *amoeba Pelomyxa* has two types of feeding reactions, one to non-moving objects, which have "no possibility of escape"; the other to objects in motion, which may escape. The latter type is much more varied and adapted to the position of the object than the former, and no existing theory of the movements of Amœba will explain it. Instead of writing merely of moving or resting stimuli, the authors seem to prefer calling them objects which may or may not escape, and almost imply a kind of foresight on the amœba's part.

Shadall (36) reports that Opalina, when in an alkaline medium, reacts positively to acids: it may cease to react to chemicals after repeated stimulation.

Schaeffer (35) continues his very important observations on Amœba. He finds that it can choose between digestible and indigestible particles. If the two kinds are stuck together, the food cup separates them. The movement of a particle is, however, the most important condition of the feeding reaction. Glass particles are eaten if they are in motion. The basis of discriminations in all the feeding reactions Schaeffer thinks is physical rather than chemical. He is on debatable ground when he conjectures that a true chemical sense does not exist anywhere, arguing that such a sense ought to inform us of the chemical constitution of bodies: one might as well urge that a true light sense does not exist because we do not see white light as complex.

Wulzen (45) observed that as soon as a hungry planarian came into diffused meat juice, it protruded and waved about its pharynx, then withdrew it and proceeded in the direction of the food. This would seem to be an interesting example of the anticipation of a consummatory reaction, of which Craig (7) speaks. If the planarian is sectioned behind the cephalic lobes and in front of the pharynx, an inhibitory influence is apparently lost and the pharynx remains extended in the meat juice, which is ingested. Some interesting observations were made on the isolated pharynx, which was

found to respond to meat juice when entirely separated from the body.

Light Reactions.—Frog tadpoles are found by Cole and Dean (5) to be sensitive to light when 40 mm. long. The skin is the most important receptor, and the tail the most sensitive region. The youngest larvæ are indifferent to light; later a photokinetic stage is reached, and the final stage is one of positive response. The mechanism is probably nervous and does not involve the melanophores.

Patten (25) has studied the reactions of the whip-tail scorpion by measuring the angular deflections from the original direction of locomotion. Both a kinetic and a directive effect of light were found, produced both by change of intensity and by constant intensity. Orientation seemed very definite.

Reese (32) reports that the crimson spotted newt collects in darkened regions in moderate temperatures, orients positively to light of all intensities, but inhibits or reverses this behavior at low temperatures. Red light produces the same effect as white, but in a less degree; green still less, and blue least.

The problem of the relative stimulating effect of different colors to organisms was investigated by Mast (17) for the following: Euglena (five species), Phacus, Trachelomonas, Gonium, Pandorina, Eudorina, Spondylomorum, Arenicola larvæ, earthworms, and blowfly larvæ. For all these certain colors were more efficient than others, but in every case a suitable change of intensity would obliterate the difference, so that no evidence of color discrimination appeared. The distribution of efficiency in the spectrum has no correspondence with the degree of species relationship: near relatives differed markedly. It is also independent of physiological state, environment, and the positive or negative character of the response. Against the contention that animals and plants are essentially alike in their responses to light, it is shown that the shorter wave lengths are relatively more efficient for green plants than for any animals.

In favor of Loeb's views Garrey (9) reports observations on the robber fly, like those made some years ago by Holmes on Ranatra, with a different conclusion. Blackening one eye, illuminating one eye, blackening or illuminating halves of the eyes, produced in each case circus movements which were in perfect accord with Loeb's tropism theory. When one eye was kept in darkness for two or three days, the fly circled to the side from which the black had been removed: this is held to be purely an effect of darkness adap-

tation. Loeb and Northrup (14) report that on Balanus larvæ the effectiveness of a light intermitted by having a sector of 90 degrees cut out of a rotating disk was to that of an equal light of constant intensity as one to four, thus corresponding to the Bunsen-Roscoe Law. On the other hand Dolley (8) urges against Loeb's continuous action theory that Vanessa does not move faster in strong light than in weak, but the reverse; it moves faster in intermittent light of a certain frequency than in continuous light. Its orientation is, he holds, due to the rate of change in intensity.

Goldsmith's (11) studies of the reactions of a cephalopod to colors are wholly devoid of any precautions against sources of error. Polimanti (28) has studied the effect of different colored lights on the respiration rates of an octopus and of fish; the method, it will be remembered, of Babak. In the case of the octopus, the number of respirations increased on passing from white to colored light: violet and blue were most effective and red least. On the fish, red produced greatest increase of respiratory rate: this Polimanti explains ingeniously by the fact that in their normal habitat such rays reach them only to a very slight degree. The colored lights were produced by solutions in the water where the animals were: it would seem to the reviewer that the chemical effect of these solutions might be a source of error.

Schaeffer (34) reports the curious observation that Amœba apparently senses a beam of either light or darkness before entering it; in fact, from a distance of 100 to 150 microns. He has no explanation to suggest.

Geotropism and Rheotropism.—Cole (4) finds that Drosophila, when creeping, is negative in its response to gravity, contrifugal force, and air currents, the stimuli being probably received by the leg muscles. Parker (24) in a study of the behavior of Corymorpha, reports the hydroid negatively geotropic, the response, as evidenced by the fact that it can be abolished by chloretone, (22) being of neuromuscular origin. The main object of the paper is to describe the neuromuscular system, which he reports as more like a reduced actinian system than a primitive one, the stalk, proboscis, and tentacles each having a mechanism. Olmsted (21) says that the geotropism of *Planaria maculata* depends on previous exposure to light and on the state of hunger or satiety. Turner (39) describes the positively geotropic movements of Euglena in quince jelly: in thin jelly the flagellum is used; in thick jelly the movement is of a different type, which is effective only on a solid support.

The fish *Epinephelus striatus* is said by Jordan (**12**) to show a negative rheotropism instead of the common positive or head to current response. The stimulus is apparently received by the lips.

Color Changes and Melanophore Reactions.—In certain crabs (Brachyura), Longley (**15**) reports that temperature is much less effective than background color in producing color changes.

Redfield (**31**) has two interesting papers on the melanophore reactions in the horned toad. These reactions are of three types: (1) a daily rhythm, darkening in morning and afternoon, lightening at midday and night (this is a local effect, occurring in skin isolated from the nervous system; it is affected by the temperature); (2) changes adapted to the substratum, involving the eyes and not occurring when the animal is blindfolded; (3) a contraction of the melanophores under nervous excitement. This last effect results from a hormone, probably adrenin, produced under nervous excitement: the melanophores are also under the direct control of the nervous system, so that there seems a high degree of resemblance between the physiological bases of emotion in reptiles and in mammals.

Rhythms and Periodic Activities.—The color rhythm in the horned toad just mentioned may be noted under this head.

Parker (**23**) says that the sea-anemone *Sagartia luciae* has a tidal rhythm of expansion and contraction: Metridium a daily rhythm. Neither of these rhythms however shows any anticipation or persistence after the stimulus is withdrawn, as certain French observers have reported. Strong light and high temperature cause retraction, food and water currents cause expansion.

Redfield (**32**) has observed that the rhythmic contractions of the mantle in lamellibranchs increase in rate during the early stages of suffocation, and that if they are checked the clams suffocate.

A rhythmic heat period, marked by a flow of secretion every sixteen days, is reported as occurring in the guinea-pig by Stockard and Papanicolaou (**38**).

Baldwin (**3**) took observations of the activities of the earthworm at twenty minute intervals for a period of one month. The total time of activity was about one third of the time: there were definite periods of activity, which fell especially in the early night hours.

Murphy reports to *Science* (**20**) a pleasing tale of a bat which he saw going in swimming in the open space of a park pond with the temperature at thirty Fahrenheit.

There has been continued discussion of rhythmic concerted activities on the part of animals. Wheeler (**43**), for example, describes rhythmic simultaneous up and down movements of Phalangidæ on their long sensitive legs. The stimulus seems to be air currents, and is propagated by the contact of the legs of the insects. Peairs (**26**) tells of how at intervals of from three to five minutes a few web-worm larvae will start a rhythmic swinging of the front of the body held erect, the movement being taken up by the others, so that for fifty seconds or so all are moving at the rate of about forty swings to a minute. Allard (**1**) thinks the synchronous rhythm in the chirping of crickets is due to their hearing each other. Gates (**10**) on the other hand says that complete synchronism in the flashing of several fireflies is a rare accident, and that a fly cannot be made to change its rhythm by flashing an electric torch. Craig (**6**) is very skeptical regarding the imitation of a rhythm in one animal by another. He calls attention to the danger of subjective rhythm on the observer's part, and maintains that mechanical transmission of rhythm through the substratum will explain practically all cases of collective rhythms.

Miscellaneous Instincts.—Wells (**42**) makes a contribution to our knowledge of the homing of limpets by showing that their path is commonly an oval, so that they do not retrace their outward course.

McCulloch and Yuasa (**16**) say that the direction of migration of Hessian fly larvæ is wholly predetermined by the orientation of the eggs; the larvæ always turn from the anterior to the posterior end of the eggs.

Rabaud (**29**) finds that the paralysis of spiders by wasps is not due to the wounding of nerve centers, but to the rapid diffusion of the poison.

Utsurikawa (**40**), comparing inbred with outbred rats, finds the latter more active, less savage, less responsive to auditory stimuli, more restless under continous stimulation but less so under momentary stimulation, more sexually different.

Craig (**7**), whose patient and original observations on animals will result, the reviewer believes, in conclusions of the utmost importance, makes some suggestive remarks on the general nature of instinct. He defines an appetite as agitation continuing in the absence of a stimulus, often beginning with an incipient consummatory reaction; an aversion is defined as agitation continuing in

presence of a stimulus. The typical cycle is (1) absence of the stimulus (appetite), (2) reception of the stimulus, (3) surfeit (aversion), (4) freedom from the stimulus, rest. Some instinctive appetites are so persistent that if they do not get the normal stimulus they make connection with an abnormal one, to which the consummatory reaction is given.

The reader who wishes to relax his mind from the scientific rigor of the foregoing summary may do so by contemplating the theory of Hiram Maxim (**18**) that cases of mimicry or protective resemblance among animals are due to the mimicking animal's perceiving by telepathy the mental processes of its enemies.

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SENSORY PHYSIOLOGY OF ANIMALS

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There has been this year a slight falling off in the proportion of of studies devoted to the sensory physiology of vertebrates. Only one paper (**6**) reports any attempt to measure differential sensitivity and in only one is the discrimination method employed (**36**). This field has been chiefly the domain of psychologists and its present barrenness is doubtless the result of the diversion of their interest to military problems. Several studies inspired by interest in animal ecology seem to promise the development of an applied science of animal behavior.

General Studies.—Olmsted (**18**) records the responses of an holothurian to pressure, gravity, light, heat, and chemicals. Hecht (**13**) studied the tactile, thermal, and chemical sensitivity of an ascidian. The studies are limited to detection of sensitivity and determination of the reflex responses.

Tactile Sensitivity.—The tactile sensitivity of a scale-covered fish, the hamlet, was examined by Crozier (**9**). Visual responses usually predominate in the behavior of this fish, but when vision is destroyed in any way it shows extreme sensitivity to slight currents in the water, reacting to wires or slender rods moving slowly at a distance of five centimeters. Cocainization or transsection of the spinal cord destroys this sensitivity but leaves some chemical sensitivity.

Parker and Van Heusen (**31**) eliminated successively the sensitivity of the lateral line organs, ear, and skin of the catfish. All these organs were found to be sensitive to slow oscillations of the

surrounding medium. All are sensitive to sound, the upper thresholds being; skin, 172 dv.; lateral line, 344 dv.; ear, 688 dv.

Sherrington (38) describes a variety of reflexes which may be elicited by stimulation of the pinna of the cat. Their thresholds for mechanical stimulation are low, for electrieal very high. They can not be classified as the result of deformation of the surface, but are due to "affective touch."

Sensitivity to Chemicals.—Crozier (6) compared the time required by earthworms to withdraw the posterior half of their bodies from solutions of sodium hydroxide and ammonium hydroxide of different concentrations. The intensity of reaction of the worms was found to be directly proportional to the concentration of the alkalis. Ammonium hydoxide is the less effective stimulating agent. From the relative efficiency of the two alkalis in penetrating cell membranes and in ordinary chemical reactions it is argued that the process of stimulation must be dependent upon a chemical reaction at the surface of the cell and not upon penetration of the cell. The author used a similar technique in a study of reactions to acids (7) and concludes that they too stimulate primarily by a surface action.

Copeland (5) found that the entire skin of marine snails is sensitive to concentrated meat-juices. Very dilute solutions stimulate only the osphradium which is so located that the water drawn in through the siphon passes across it. As the siphon is moved about it draws in solutions of varying concentration and the snails orient in the direction of the stronger stimulus. Hamilton (12) records the reactions of moist-soil dwelling insects to gradient of evaporation, temperature, carbon dioxide, and ammonia. Reactions were obtained in all these gradients but the sense organs involved and the mechanism of orientation were not determined. Weese describes the reactions of the horned lizard to gradients of air humidity, air temperature, and substratum temperature. The animals avoid air of high evaporating power, select an air temperature between 35 and 40 degrees. Chenoweth (2) tested the sensitivity of the white-footed mouse to gradients of evaporating power of air. The mice chose the moister end of the cage most frequently. No indication of the sensory mechanism involved is given. These three studies were directed primarily to determine the form of stimulation which leads to the selection of habitat. In each case the animals were found to select an optimum of temperature and moisture corresponding to their normal habitat.

Static and Auditory Sensitivity.—Lyon (**25**) chilled Paramecia until they no longer reacted to gravity, then centrifuged them and found that the anterior ends are heavier. This answers the criticism that his earlier results may have been due to active orientation by the animals. Kanda (**20**) also finds the anterior end of Paramecium the heavier. In the centrifuge granules are thrown into the anterior end of the animals, along with the nuclei. Geotropism reappears when the nuclei and granules regain their original positions. Data are presented to show that apparent reversal of the direction of orientation to gravity as a result of changes in temperature or chemical composition of the medium is due to the mechanical shock of transfer or to reduction in the activity of the animals.

Parker (**29**, **30**) finds that the hydroid, Corymorpha, orients to gravity by what appears to be a true neuro-muscular reaction. Olmsted (**27**) gives evidence for geotropic responses in planaria. These vary with the degree of hunger and of exposure to light.

Turner (**39**) describes some experiments which indicate the lack of any specific reactions to gravity in caterpillars. Fruit flies, walking, orient negatively to gravity. Cole (**3**) sought to discover if gravity acts as a stimulation to activity as well as to orientation. Tests with stationary tubes involve mechanical stimulation when the flies are put under the experimental conditions. To avoid this and so test the kinetic effects of gravity Cole centrifuged the flies and found that they reacted negatively to the centrifugal force, from which he concludes that gravity alone can act as a stimulus to activity. No mention is made of measures to prevent vibration of the centrifuge.

Johnson (**18**) describes the structure and development of the lateral line organs of selachians and gives a brief review of the literature of this field.

Hussey (**17**) reports observations on the reinforcing effects of auditory and visual stimuli upon birds in the field.

Parker and Van Heusen (**31**) ascribe auditory function to the skin, lateral line organs, and ears of the catfish.

Hunter (**16**) has devised a technique for study of audition in the rat by interference of stimuli. He presents data bearing upon problems of habit-formation and promises the results bearing upon audition in a later paper.

Sensitivity to Light.—Laurens and Hooker (**23**) describe apparatus for producing a series of spectral lights of equal energy. They

use a constant-deviation spectrometer and their method of calibration does not differ essentially from that of earlier workers.

The eye of the flat-worm, Prorhynchus, consists of a single retinal cell and an accessory pigment cell. Kepner and Foshee (21)find that the pigment cell expands in darkness and contracts in light. The retinula shows three regions resembling the divisions of the vertebrate retinal cell. In light the rhabdome is rounded, the refractive segment is large (at an optimum illumination), and the nuclear part of the cell in narrowed. In darkness the rhabdome becomes flattened and the nuclear part of the cell grows wider. The functional changes, therefore, do not correspond to those shown by the vertebrate retinulæ. Laurens and Williams (24) compared the photochemical changes in the normal eyes of Amblystoma larvæ with those occuring in transplanted eyes having no connection with the central nervous system. Changes in distribution of pigment and length of cone myoids in alteration from light to darkness adaptation were found to be greater in transplanted eyes than in normal ones. This seems to agree with Arey's suggestion of the existence of inhibiting fibers in the oculomotor nerve.

Laurens (22) finds that in both normal and eyeless Amblystoma larvæ the melanophores contract in darkness and expand in light. These conditions are permanent in eyeless individuals, but normal animals after three or more days exposure to light or darkness show a "secondary reaction" which produces a nearly complete reversal of the first condition. This response is mediated through the eyes and is apparently an adaptation to the background. According to Bray (1) the melanophores of the catfish contract in light and expand in darkness. But if the fish are badly frightened they may remain light in color even after days in darkness. Adrenalin is found to produce contraction and Bray suggests that the contraction of melanophores in frightened fish may be due to the action of a hormone. Redfield (34) finds that the melanophores of the horned lizard react to light, temperature, color of the substratum, and exciting stimuli. The latter is probably the result of adrenalin production.

Dolley (10) gives an extensive account of the reactions of Vanessa to light. Circus movements appear when one eye of the insects is rendered nonfunctional but the deflection from the straight course is not proportional to the intensity of the light. In very low intensity of light there is a reversal of the direction of circus movements. These, with other facts, indicate that the response is to

change of intensity and not to the continuous action of the light. In a later study (11) he measured the rate of locomotion in Vanessa toward lights of different intensity and found that they move more rapidly in response to dim light than to direct sunlight. They also move more rapidly in response to a beam of light interrupted 10 to 16 times per second than to a continuous light of the same intensity. This is in contradiction to Loeb's theory of the continuous action of light in orientation. Holmes (15) verifies his observations of the effects of continuous action of light in the orientation of Vanessa, with more careful controls.

In a preliminary study Patten (32) describes the reactions of the whip-tail scorpion to light. The animals are regularly negative in their responses to all intensities between 120 and 0.16 m.c. They give no evidence of reaction to visual objects. When the median or lateral eye-groups of one side are blinded circus movements result. McEwen (26) finds that when the wings of the fruit fly are cut off the reactions of the insects to light almost disappear and the loss of phototropism is proportional to the amount of wing destroyed. A number of hereditary strains of partly wingless flies are available and in them also the responses to light are proportional to the degree of defect of the wings. There are probably no light receptors in the wings; the phenomenon seems to be one of sensory reinforcement. A strain of flies has been found in which a lack of phototropism is associated with tan body pigment and is inherited as a Mendelian recessive. The various eye-color mutants to not have identical sensitivity to different wave lengths of light. For the dark eyed flies red light has relatively greater stimulating value.

Crozier (8) states that Balanoglosids orient negatively to light. The proboscis is most sensitive. Light production by the animals is inhibited by exposure to light.

Van Heusen (40) finds that catfishes from which the eyes have been removed retain sensitivity to light. The skin of the hamlet is also found photosensitive by Jordan (19). The time required for stimulation is inversely proportional to the intensity of the light.

Cole and Dean (4) find that the tadpoles of *Rana clamitans*, 40 or more centimeters in length, show greater activity in light than in darkness. Some large specimens were positive to light. Reese (35) reports experiments to show that the spotted salamander is negatively phototropic, losing the reaction at high and low temperatures. While they gather in shaded parts of the aquarium they tend to go directly toward the source of light.

Pearce (33) trained rats to react to light versus darkness, using a method similar to that of Hunter for sound. The visual response is learned more rapidly than the auditory. Similar results have been obtained in studies of the conditioned reflex, but no suggestion has yet been made to account for the greater difficulty in associating a reaction with one rather than another form of stimulation.

Rochon-Duvigneaud (37) gives a summary of the relative number and size of the rods and cones in various reptiles and birds and discusses briefly their function in day and night vision.

Reeves (36) shows that the rat may learn to distinguish between stationary and moving lights and that they have an instinctive tendency to go toward the moving light. This accords with the general concept that a moving stimulus has greater efficiency than a stationary one.

In a lecture before the Morphological Society of Munich Hess (14) summarizes the results of experiments upon the light reactions of a number of animals. In the alcoipid he finds a new method of visual adaptation to distance. Fluid is forced into the vitreous sac from an adjacent bulb. Hess has continued his studies of color-vision by the method of pupillary response and the contractions of the pupils of normal and color blind men in different wave-lengths of light were measured for comparison with results obtained on animals.

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SPECIAL REVIEW

The Animal Mind. A Text-book of Comparative Psychology. MARGARET FLOY WASHBURN. 2d Edition. New York: Macmillan, 1917. Pp. xii + 386.

The second edition of this text represents considerable revision. The obvious changes consist for the most part of, *a*, the inclusion of the later experimental data to bring the book up to date, *b*, the omission or curtailment of some of the older material in the interests of space, *c*, the amplification of certain positions and doctrines where greater clearness was demanded, and, *d*, a reorganization of the mode of presenting and treating certain topics. There has been no change in point of view, or in the general plan of the text.

The topical organization of chapters 1, 2, 4, 6, and 13 of the older text has not been latered. The topics concerning the paramecium and tropisms have been omitted in chapter 3. A new section on the chemical sense of Protozoa has been added in chapter 5. Chapter 7 on vision has been pretty thoroughly reorganized, more space being devoted to its consideration than formerly. Chapters 8 and 9 devoted to spatial reactions have been altered. The topical outline for orientation to gravity is the same as formerly, while the treatment of orientation to light has been revised. The homing reaction of animals has been included as one of the evidences of image vision. The most pronounced alteration concerns chapters 10, 11, and 12. These were condensed into two chapters and the material is presented in a different manner. On the whole the revised organization represents a distinct improvement in clarity of presentation.

The doctrine that subjectivism constitutes the proper goal of comparative psychology has been re-affirmed with considerable emphasis. "There exists an inner aspect to behavior, the realm of sensations, feelings, and thoughts, which is not itself identical with behavior or with any form of movement. . . . Our object in this book will always be the interpretation of the inner aspect of the behavior of animals; we shall be interested in what animals do only as it throws light upon what they feel. To the true psychologist, no challenge is so enticing as that presented by the problem of how it feels to be another person or another animal; and although we

must sometimes give up the problem in despair yet we have also our successes. We have wonderfully advanced, within the last twenty-five years, in knowledge as to how the world looks from the point of view of our brother animals." This plan has been followed rather consistently for the most part, but here and there, I suspect, a critical and unsympathetic reader may find statements of fact and descriptions of behavior which are not utilized in any obvious fashion in interpreting the inner life of animals. Section 80 is devoted to a consideration of the relation of age, sex, individual differences, and distribution of effort to the learning process, but the significance of these facts for inner experience is not discussed.

The chapter on the Evidence of Mind has been introduced by a new paragraph. "In this chapter we shall try to show that there exists no evidence for denying mind to any animals, if we do not deny it to all; in other words, that there is no such thing as an objective proof of the presence of mind, whose absence may be regarded as proof of the absence of mind." Such a statement may raise the question in the minds of some readers whether the author believes in the existence of an animal mind and as to what are the grounds of her belief. Later we are told that we know beyond a reasonable doubt that mind exists in those animals of a structure resembling ours which rapidly adapt themselves to the lessons of experience. The structure of all animals resembles ours to some extent; it is a matter of the degree of resemblance. How similar the resemblance and how rapid the adaptation are questions which are not discussed.

The treatment of the learning process has been considerably modified. The data are discussed under four headings,—the dropping out of movements, the formation of a series of movements, the recognition of landmarks, and learning involving the anticipation of movements. The second topic is new. Movements tend to be abandoned when they mediate consequences of no importance to the organism. The illustrations cited are those of adaptation. Movements with harmful consequences are eliminated because of the initiation of more prepotent tendencies, and useless acts are dropped because of the survival of successful responses. Ideas are involved when movements are anticipated. Cole's experiments do not prove the existence of ideas. But three types of experiment demonstrate the presence of ideas. The multiple choice method is efficacious only when the animal succeeds in choosing the *middle* door of a series. The second is the delayed reaction test. Ideas

are necessary in inferential imitation, and this type of response has been demonstrated for the monkey by Kinnaman and Haggerty.

The adoption of the subjective position will meet approval in some quarters and dissent in others. Such a division of opinion is not subject to argument. Ultimate values are rarely susceptible to profitable discussion. Those who are interested in the nature of the inner experience of animals as an end in itself are not likely to be dissuaded from their purpose by the arguments of the behaviorists, and to a behaviorist the continual quest for the psychic necessarily constitutes a futile, distracting and useless undertaking.

Opinions will differ as to the value of the book as a text. Naturally the behaviorists will find some difficulty in adapting the book to their needs. Others will possibly maintain that too much space has been devoted to sensation at the expense of the learning process. Some of the reviewer's students have complained of becoming lost and confused in the mass of detail in certain of the chapters on sensation and space. However, no text will meet with universal favor.

Practically all students of animal behavior are agreed as to the worth of the book for purposes of reference. Good judgment has been exercised in the selection of material. The material has been carefully digested, well organized, critically evaluated and for the most part clearly presented. The book represents the most exhaustive and complete summary of the experimental literature now extant. For the serious student of comparative psychology the book has proved to be invaluable.

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